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ABSTRACT

This study was designed to examine effects that access to manipulatives in science instruction have with respect to the development of spatial conceptual abilities and whether the effects were different for males and females. A secondary purpose of this investigation was to examine what relationship sex and access to manipulatives in conjunction with sex has on the development of projective spatial ability. The sample consisted of 52 fifth-grade students. The experimental group received instruction using the Energy Sources unit from SCIIS, while the control group's instruction was designed around a science textbook. Spatial ability data was gathered from both groups utilizing a battery of three Piagetian-type tasks. The study concludes that both males and females benefit from access to manipulatives in the development of projective spatial abilities. (Author/DS)

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The Use of Manipulatives and Their Effect on the Development on Spatial Conceptualizations

by
Herbert G. Cohen

Introduction

The primary purpose of this investigation was to examine what effects the access to manipulatives had on the development of projective spatial conceptual ability.

Many of today's classrooms utilize science curricula which incorporate the use of manipulatives. These curricula are purported to be of greater value in fostering the development of cognitive processes including spatial conceptual ability and the attainment of science processes and science content than those curricula utilizing other approaches, such as lecture, reading, demonstration or a mixture of these approaches.

The use of manipulatives has been advocated for some time (Montessori, 1912 and Dewey, 1916). More recently, the use of manipulatives has been supported by such theorists as Piaget (1964), Bruner (1965) and Gagne (1965). Piaget's ideas are those most frequently cited as a basis for the incorporation of manipulatives into science curricula. Piaget contended that experience is one of the factors mediating cognitive development, the other three being maturation, social transmission and equilibration. According to Piaget knowledge is linked with actions. To know an object a subject must act upon it, and thus transform it; that is, displace, connect, combine, take apart and reassemble it.

Research findings in science education suggest that while the use of manipulatives may be important for various forms of learning in some instances it appears to make little difference in others (Benson, 1966; Brown, 1968; Cohen, 1980; Halsted, 1973; Herron, Jans, Van Neie, Luce and O'Heron, 1974; Hill and Obenauf, 1979; Linn and Thier, 1975; and Macbeth, 1974). For

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example, Macbeth (1974) examined kindergarten and third grade children. Some of the children in his study had science lessons with manipulatives while others were simply allowed to observe. He concluded that kindergarten children having access to manipulatives learned more from science lessons than those children merely observing. These results were not repeated with the third graders. Halsted (1973) examining high school students found that students appeared to learn more when they were actively involved in making models of chemical compounds than when just observing someone else do this. It may be questioned whether the results of both of these studies may be due to either the students' attending behavior or their level of intellectual development. No existing evidence was identified to resolve this question.

Linn and Thier investigated fifth graders who studied energy sources from SCIS and fifth and eighth graders who did not have any exposure to this unit or any other science material using manipulatives. They concluded that the logical thinking of the fifth graders having access to the materials was better than that of the fifth graders having no access to manipulatives, and was about equal to the logical thinking of the eight graders studied.

Cohen (1980) examined first, third and fifth grade students, half of whom were having science instruction with SCIS materials, while the remaining half had no science instruction. On a battery of six Piagetian-type tasks designed to examine topological spatial abilities there was no statistically significant difference in their spatial abilities.

None of the above studies resolve whether or not the use of manipulatives actually enhances the development of cognitive abilities in general, and thus this still is an area of concern to science educators.

A specific area which some science educators have been concerned with is the development of spatial conceptual abilities. As Hill and Obenauf (1979) state:

> "An understanding of the relationship of spatial visualization, problem solving, and cognitive development has been of interest to science educators. This understanding could provide useful insights for the developers of both curricular and instructional materials for the teaching of science."

This study was designed to examine effects that access to manipulatives in science instruction has with respect to the development of spatial conceptual abilities and whether that effect was different for males and females. A secondary purpose of this investigation was to examine what relationship gender and access to manipulatives in conjunction with gender has on the development of projective spatial ability.

Method

Sample

The sample for this study consisted of 52 fifth grade students enrolled in two classes, in a middle-income, suburban Phoenix elementary school district. A small portion of the population come from an outlying area which is a low-income area.

The mean age of the subjects in the sample was 10 years, 9 months at the mid-point of the investigation. Dettrick (1974) suggests that projective spatial conceptualizations are not completed until 12 or 13 years of age, although Inhelder and Piaget (1948) suggest a 9 or 10 years of age. There were twenty-four females and nineteen males in the study sample.

Procedure

Students were assigned to either the experimental or control group. This assignment was done in a randomized fashion in order to assure lack of initial bias between the groups. According to Campbell and Stanley (1966) randomization can suffice without pretest.

The experimental group received instruction using the Energy Sources unit from SCIIS (2nd edition, Rand McNally). This unit focuses on matter and energy and begins with a review of the notions of property, interaction, system, subsystem and variable. The remainder of the unit deals with notions of energy source, energy receiver, energy transfer and energy chain. Temperature change or motion provides evidence of energy transfers.

The suggested SCIIS strategies for these materials were modified to make the instruction individualized. The control group's instruction was designed around a textbook, Learning Science - LS, Glencoe-Macmillan. A group of science educators were polled and independently determined that the content of and processes covered in the LS chapters used in the study (Systems in Action; Energy Chains; Energy Sources; Change in Forms; and Action Producers) was parallel to those contained in the Energy Source unit from SCIIS. The treatment period extended from November, 1979 through mid-February, 1980. Each group received two 25-30 minute instructional sessions twice a week.

The SCIIS instruction involved the manipulation of concrete objects and was student-centered. In contrast, the textbook oriented class was teacher-directed, and the focus was on written rather than manipulative exercises.

In both experimental groups the instructor exhibited behaviors which were intended to promote inquiry and intellectual growth. Verbal practices included the use of divergent, higher level questions, appropriate wait-time and the offering of alternative activities for students to pursue.

Instrumentation

In order to collect data on spatial abilities a battery of three Piagetian-type tasks were individually administered to each of the subjects in the study.

The three tasks were derived from the following groupings: IP_1 (Addition and Subtraction of Projective Elements); IP_5 (Rectilinear Order); and, IP_6

(Symmetrical Internal Relations)*. The tasks used in this study are described elsewhere (Doyle, 1977; and Treagust, 1980) and were designed on the basis of information provided by Piaget and Inhelder (1948). Each task was designed to ascertain whether a subject possessed the cognitive ability described by a grouping. The concept of grouping is central to Piaget's explanation of how thought develops during the concrete operational stage and how the child is able to operate in his or her world and understand it. These groupings are considered to be models of how people think in several areas of intellectual endeavors, and attempt to symbolically express what is implied by a child's actions. If a subject successfully completed a task, it was inferred that the subject possessed that grouping. The tasks were administered in a random order and each task was scored on the basis of predetermined criteria. Subjects were permitted to interact with the objects (either overtly or representationally) and responded to questions regarding his or her actions upon the objects. The protocols required that the subject supply an acceptable reason for a choice.

These tasks had been previously evaluated by individuals familiar with Piagetian research and they ascertained that the tasks examine the groupings for which they were designed. In order to provide a reliability check of the scoring and evaluation of interviews, a second person scored a random sample of the interviews. This procedure assured consistency in the scoring of task responses on the part of the investigator.

Scoring

For the purposes of analysis, only those subjects who completed each part of a task without any errors were given a "pass" (1). Otherwise, the

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* I = infralogical; P = projective; and the numbers correspond to each grouping's homolog in the logical groupings.

subjects were given a "fail" (0) for that task. A subject potentially could earn a score of up to 3 points from the projective tasks. To test for significant differences in performance between the experimental and control group, a chi-square procedure for two independent samples with correction for continuity was used (Siegal, 1965). This procedure was also applied to the data in order to see if there were any significant differences in performance between males and females.

Results and Discussion

The data on the battery of Piagetian-type tasks comparing performance between experimental and control groups is presented in Table 1. The chi-square test for differences between groups was statistically convincing ($x^2 = 7.82$, $p \leq .05$; $df = 1$). This suggests that the experimental group's

Place TABLE I about here

projective spatial ability was greater than that of the control groups at the end of the instructional sequence.

Although through random assignment to treatment groups, it may be presumed the groups were initially equal in spatial ability, it is not possible to determine whether the control group's ability improved, decreased or remained constant.

The data in TABLE II shows task performance of males and females. A

Place TABLE II about here

chi-square test of difference in group performance was statistically convincing ($x^2 = 5.66$, $p \leq .05$; $df = 1$). This suggests that males benefit more from science experiences, with respect to development of projective

spatial abilities, than do females. This generally supports Treagust's (1980) findings that on the average, males and female's spatial ability develops at differing rates.

Finally, the data presented in TABLE III compares task performance between males in both treatment groups, and the data presented in TABLE IV compares the task performance of females in both treatment groups. The chi-

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Place TABLES III and IV about here

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test for differences between groups was statistically convincing in both cases (males: $x^2 = 4.01$; females: $x^2 = 4.55$; $p \leq .05$; $df = 1$). From these results one can conclude that even though males may benefit to a greater extent than females with respect to the development of projective spatial abilities, access to manipulatives still benefits an individual regardless of gender.

Implications

Benefits with respect to the development of projective spatial conceptual abilities can be enhanced during science experiences if these experiences incorporate the use of manipulatives. The resulting higher levels of spatial abilities should enable the children to gain more understanding from other academic encounters - not only those in which physical models are employed but also where the student is expected to make use of two-dimensional displays - such as drawings, photographs and diagrams - and make mental transformations of these displays into three-dimensional transformations. Furthermore, the development of higher levels of spatial conceptual abilities is necessary for acquisition of functional knowledge in science where spatial relations are the underpinnings of such knowledge.

Finally, the findings of this study speak loudly to the notion that any science program used with elementary-age children, which has at its core of goals the development of thinking, should rely much more heavily on first-hand manipulative experiences as opposed to the reading of textural material. The resulting higher thinking abilities should increase student's ability to comprehend in meaningful ways.

TABLE 1

Task Performance of Experimental and Control Groups

Group	N	Tasks *1
Expt	26	49
Control	26	29
Total	52	78
χ^2		7.82

*1 Total possible for each group = 3 x N

*2 $p < .05$ ($df = 1$)

TABLE II

Task Performance Between Males and Females

Group	N	Tasks *1
Male	22	33
Female	30	45
Total	52	78
X^2		5.66*2

*1 Total possible for each group = 3 X N

*2 Significant at 0.05 level, df = 1

TABLE III

Analysis of Task Performance Between Males in Experimental and Control Groups

Group	N	Tasks*1
Expt	9	18
Control	13	15
Total	22	33
χ^2		4.01*2

*1 Total possible for each group = 3 X N

*2 Significant at 0.05 level, df = 1

TABLE IV

Analysis of Task Performance Between Females in Experimental and Control Groups

Group	N	Tasks*1
Expt	17	31
Control	13	14
Total	30	45
χ^2		4.55*2

*1 Total possible for each group = 3 X N

*2 Significant at 0.05 level, df = 1

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